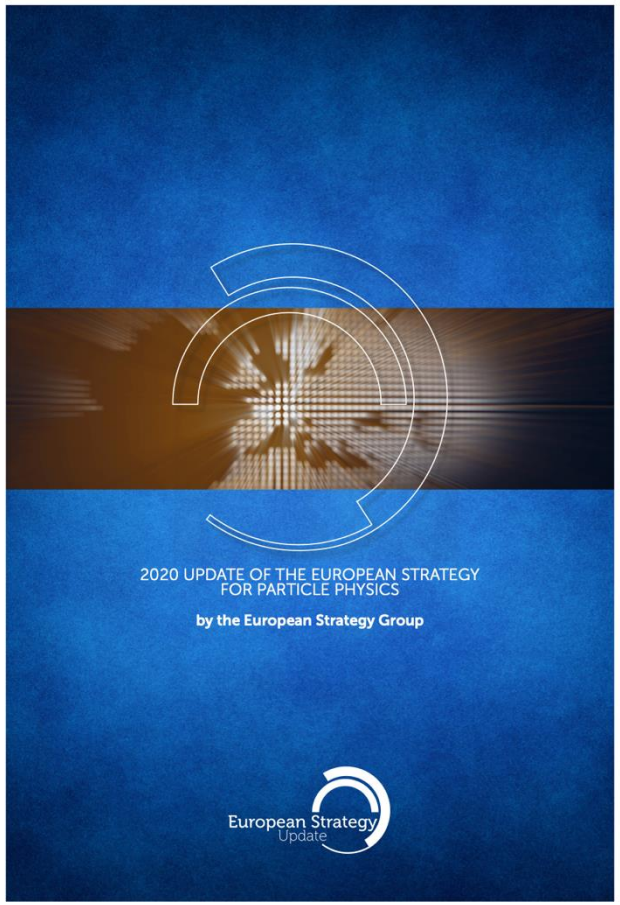
SUSTAINABILITY & ESPP 2026

Peter Millington

UKRI Future Leaders Fellow
University of Manchester
DESY FH Sustainability Forum, 23 June 2025

ESPP 2020



We need a commitment stronger than this.

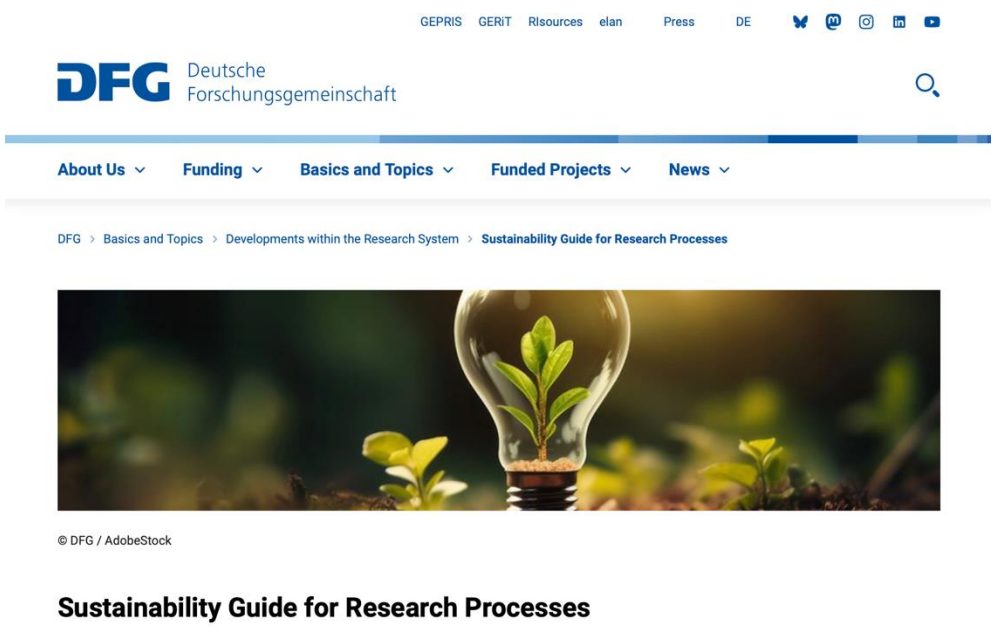
7

Environmental and societal impact

A. The energy efficiency of present and future accelerators, and of computing facilities, is and should remain an area requiring constant attention. Travel also represents an environmental challenge, due to the international nature of the field. ***The environmental impact of particle physics activities should continue to be carefully studied and minimised. A detailed plan for the minimisation of environmental impact and for the saving and re-use of energy should be part of the approval process for any major project. Alternatives to travel should be explored and encouraged.***

http://dx.doi.org/10.17181/CERN.JSC6.W89E

The landscape is changing.



The Heidelberg Agreement on Environmental Sustainability in Research Funding

Philipp M. Weber[1✉], Sandra Bendiscioli[1✉], Gerlind Wallon[1], Uwe von Ahsen[2], Anne Marie de Beaufort[3], Marion Boland[4], Florijn Dekkers[5], Dominique Dunon-Bluteau[6], Martin Farley[7], Alyson Fox[8], Stéphane Guillot[9], Loic Lannelongue[10], Marta Łazarowicz-Kowalik[11], Brendan Rouse[12], Gabrielle Samuel[13], Teresa Sanchis[14], Susan Simon[15], Mathew Tata[16], Gisou van der Goot[17] and Fiona M. Watt[1]

Preamble

If we want to provide the basis for future generations to prosper, we need an urgent shift towards a culture of sustainability[a]. At this critical time, the science sector is recognizing its important role in promoting sustainability and the need to understand its own environmental and social impacts.

Funding agencies play a central role in enabling researchers to conduct their work. Funders' strategic decisions can influence which questions are tackled by researchers. By setting conditions for their funding schemes, funders can change research practice towards sustainability. The responsibility of funding agencies to support the United Nations' 2030 Agenda for Sustainable Development was recently highlighted by the Global Research Council's Statement of Principles on Sustainable Research[1]. To explore how funders can incentivise sustainable practices in research, they should align their goals and actions and enter a dialogue with researchers and their institutions.

The Heidelberg Agreement, a multi-stakeholder alignment, is the outcome of discussions at an EMBO workshop on *Funders' Role in Promoting Environmentally Sustainable Lab Research*[2] that took place in Heidelberg in May 2024. For the first time, a group of representatives from funding agencies, research organisations, grassroots initiatives, social scientists and experts from nine different European countries (see Participant list on page 5) worked together to agree on principles and recommendations for research funders on how to embed sustainable practices via research funding. The workshop discussions focused on sustainability in life science laboratory research. However, the outcomes represent general considerations and principles that can be applied more broadly to all research areas. The Heidelberg Agreement is not intended to be, and shall not constitute in any way, a binding or legal agreement, or impose any legal obligation or duty.

The Heidelberg Agreement was endorsed by the following European organisations attending the workshop:

Austrian Science Fund (FWF), Dutch Research Council (NWO), EMBO, European Molecular Biology Laboratory (EMBL), Foundation for Polish Science (FNP), French National Research Agency (ANR), German Research Foundation (DFG), Green Algorithms Initiative, Green Labs Netherlands (GLN), Institute for Bioengineering of Catalonia (IBEC), Medical Research Council (MRC), National Centre for Scientific Research (CNRS), UK Research and Innovation (UKRI) and Wellcome.

[1] EMBO, Heidelberg, Germany
[2] Austrian Science Fund (FWF), Vienna, Austria
[3] Dutch Research Council (NWO), The Hague and Utrecht, The Netherlands
[4] Taighde Éireann - Research Ireland, Dublin, Ireland
[5] Green Labs Netherlands Foundation (GLN) and UMC Utrecht, Utrecht, The Netherlands
[6] French National Research Agency (ANR), Paris, France
[7] UK Research and Innovation (UKRI), London, UK
[8] Wellcome, London, UK
[9] National Centre for Scientific Research (CNRS), Paris, France
[10] University of Cambridge and Green Algorithms Initiative, Cambridge, UK
[11] Foundation for Polish Science (FNP), Warsaw, Poland
[12] European Molecular Biology Laboratory (EMBL), Heidelberg, Germany
[13] King's College London, London, UK
[14] Institute for Bioengineering of Catalonia (IBEC), Barcelona, Spain
[15] UK Research and Innovation (UKRI) and Medical Research Council (MRC), London, UK
[16] Cancer Research UK (CRUK), London, UK
[17] École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland

[✉] Correspondence: philipp.weber@embo.org and policy@embo.org

Authors are listed in alphabetical order except the first three authors who contributed equally. The views expressed are those of the authors and do not necessarily reflect the views of their organisations.

[a] In future, we, the authors, envision a culture of sustainability that has only a positive impact on people and the planet. This vision is in line with the globally recognized aspirations of the 2030 UN Agenda and its sustainable development goals, which encompass social, environmental and economic considerations.

ESPP 2020

At least **2** inputs mentioned sustainability.*

PERLE : A High Power Energy Recovery Facility for Europe

A Contribution to the Update of the European Strategy on Particle Physics

Cockcroft Institute, AsTEC Daresbury, TU Darmstadt, BINP Novosibirsk, CERN, Liverpool University, IPN and LAL Orsay, Jefferson Laboratory, CEA Saclay

Contact Persons: Max Klein (Liverpool) and Achille Stocchi (Orsay)

Input to the European Strategy Update: Ensuring the Future of Particle Physics in a More Sustainable World

Veronique Boisvert (Royal Holloway, University of London)
Chamkaur Ghag (University College London)
Francesco Spano (Royal Holloway, University of London)
David Waters (University College London)
+ 291 signatures

*Based on unsophisticated searches.

ESPP 2026

At least **30** inputs mention sustainability.*

Sustainability Assessment of Future Accelerators

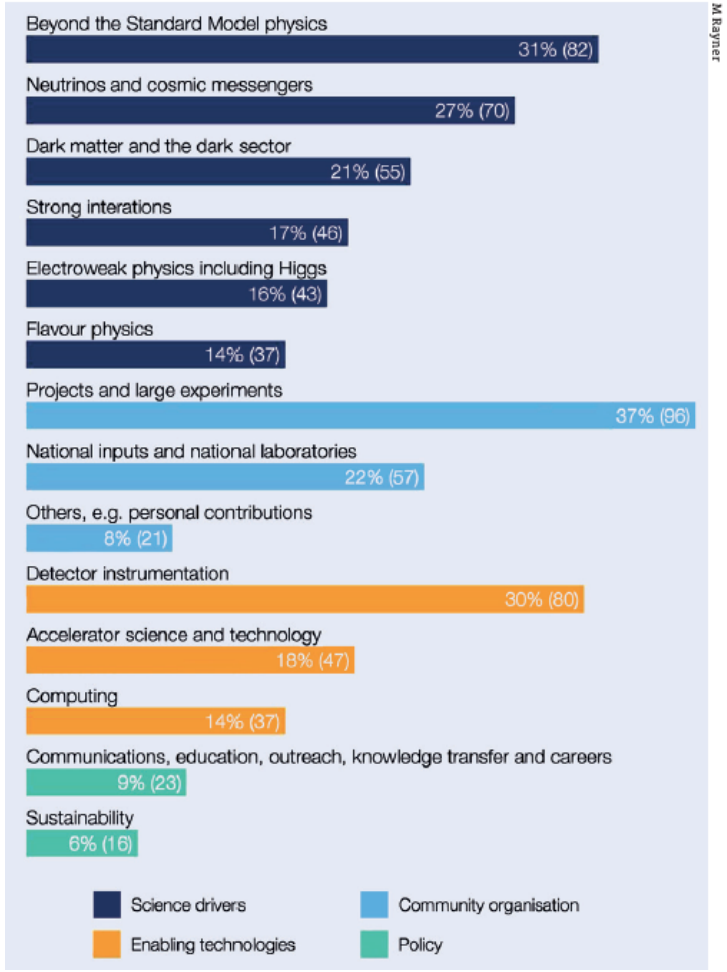
Input to the European Strategy process
by the LDG Working Group on Sustainability

edited by C. Bloise*, M. Titov†
with contributions from E. Cennini, J. Gutleber, W. Kaabi, A. Klumpp, P. Koppenburg, Y. Li, B. List, R. Losito, B. Mandelli, E.A. Nanni, N. Neufeld, T. Schoerner-Sadenius, B. Shepherd, V. Shiltsev, S. Stapnes, L. Ulrici, H. Wakeling

30 March 2025

Input to European Strategy Update for Particle Physics: Sustainability

Veronique Boisvert[1], *Daniel Britzger*[2], *Samuel Calvet*[3], *Yann Coadou*[4], *Caterina Doglioni*[5], *Julien Faivre*[6], *Patrick Koppenburg*[7], *Valerie S. Lang*[8], *Kristin Lohwasser*[9], *Zach Marshall*[10], *Rakhi Mahbubani*[11], *Peter Millington*[5], *Tomoko Muranaka*[12], *Karolos Potamianos*[13], *Ruth Pöttgen*[14], *Hannah Wakeling*[15], *Efe Yazgan*[16]



Source: Karl Jacobs, ESPP Open Symposium
Venice, 23 June 2025

*Based on unsophisticated searches.

ESPP 2026

At least **30** inputs mention sustainability.*

Sustainability Assessment of Future Accelerators

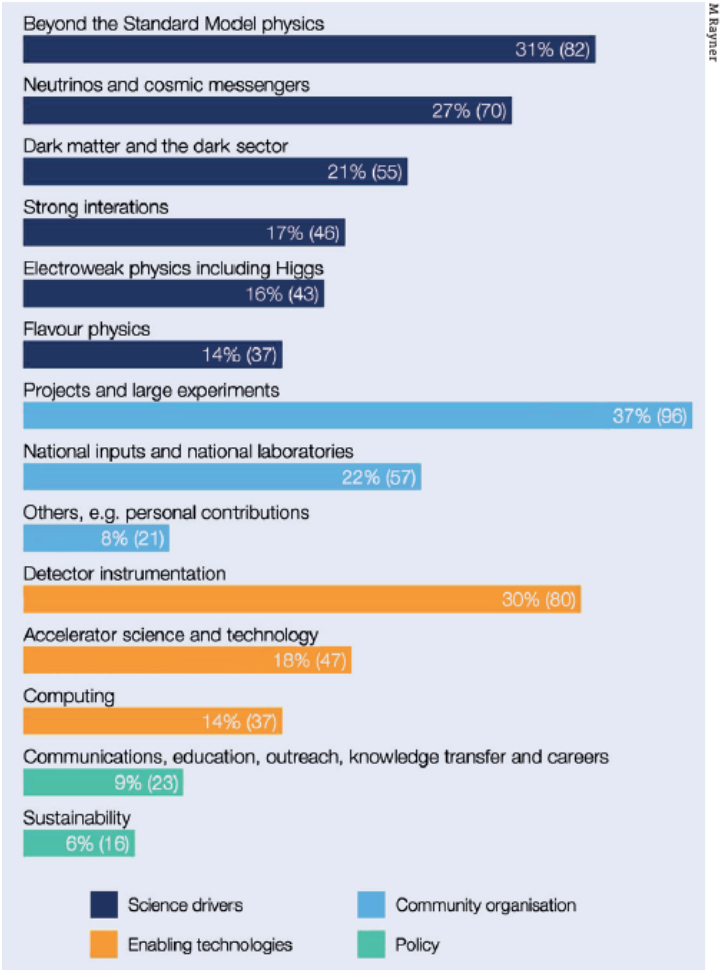
Input to the European Strategy process
by the LDG Working Group on Sustainability

edited by C. Bloise*, M. Titov†
with contributions from E. Cennini, J. Gutleber, W. Kaabi, A. Klumpp,
P. Koppenburg, Y. Li, B. List, R. Losito, B. Mandelli, E.A. Nanni, N. Neufeld,
T. Schoerner-Sadenius, B. Shepherd, V. Shiltsev, S. Stapnes, L. Ulrici, H. Wakeling

30 March 2025

Input to European Strategy Update for Particle Physics: Sustainability

Veronique Boisvert[1], *Daniel Britzger*[2], *Samuel Calvet*[3], *Yann Coadou*[4], *Caterina Doglioni*[5], *Julien Faivre*[6], *Patrick Koppenburg*[7], *Valerie S. Lang*[8], *Kristin Lohwasser*[9], *Zach Marshall*[10], *Rakhi Mahbubani*[11], *Peter Millington*[5], *Tomoko Muranaka*[12], *Karolos Potamianos*[13], *Ruth Pöttgen*[14], *Hannah Wakeling*[15], *Efe Yazgan*[16]



Source: Karl Jacobs, ESPP Open Symposium
Venice, 23 June 2025

*Based on unsophisticated searches.

ECFA Guidance

3) **Questions to be considered by countries/regions when forming and submitting their "national input" to the ESPP:**
   a) Which is the preferred next major/flagship collider project for CERN?
   b) What are the most important elements in the response to 3a)?
      i. Physics potential
      ii. Long-term perspective
      iii. Financial and human resources: requirements and effect on other projects
      iv. Timing
      v. Careers and training
      vi. Sustainability

https://ecfa.web.cern.ch/ecfa-guidelines-inputs-national-hep-communities-european-strategy-particle-physics-0

Schedule

"Implementing a modest delay in the schedule of the next generation of colliders would **allow for the implementation of mitigation measures**, while simultaneously providing time to fully exploit the physics potential of the HL-LHC."

Boisvert et al., https://arxiv.org/abs/2504.03012

See also "A flexible strategy for the future of particle physics at CERN" for emphasis on "**strategic compromise**".

Abramowicz et al., https://indico.cern.ch/event/1439855/contributions/6461672/

Some quotes

“Our research activities and research infrastructure **must aim to minimize resource consumption and negative impacts on the environment**, while exploring how research and development through our international collaborations can further contribute to the **UN Sustainable Development Goals**.”

Statement by the German Particle Physics Community as Input to the Update of the European Strategy for Particle Physics

“**environmental sustainability must remain a guiding principle**"

Spanish national input to the European Strategy for Particle Physics

Some quotes

“the next flagship collider should be built and run in the most sustainable way”

Early Career Researcher Input to the European Strategy for Particle Physics Update

“Sustainability scored fourth among all categories of respondents”

Early Career Researcher Input to the European Strategy for Particle Physics Update: White Paper

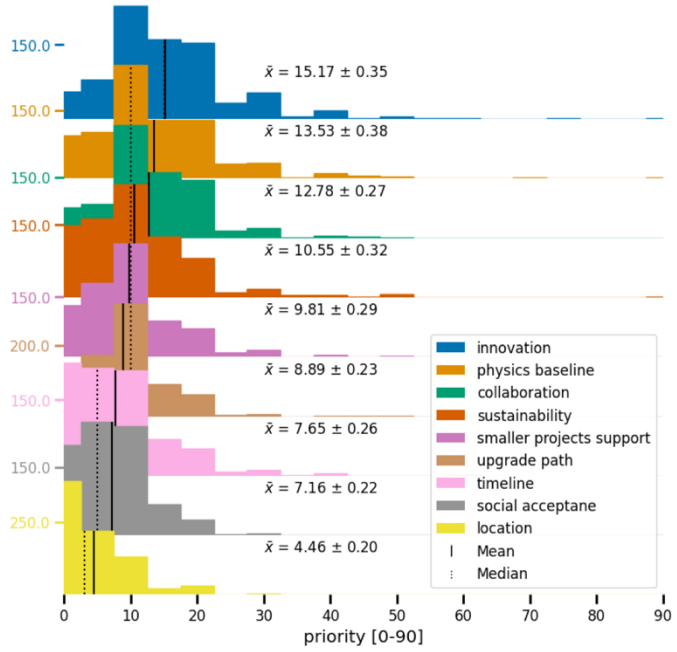


Figure 10: Ridgeline plot of the response distributions for all criteria ordered by the mean value of responses. The vertical solid line shows the mean value of all responses, while the vertical dotted line depicts the median of all responses. Note the differences in normalisation for the different criteria.

Some quotes

"**Sustainability considerations in HEP are pivotal**, to respect the planetary boundaries, to comply with the rapidly evolving regulation, and to align with the global effort demanded on society. The **HEP community should lead by example** by addressing these issues from the earliest stages of future projects, thereby **increasing their acceptance by civil society and strengthening the staff's engagement**."

French HEP community input to the European Strategy for Particle Physics

"While **sensibility to this theme varies by country**, it is obvious that as time evolves, the sustainability of our research will play a more and more important role in our lives. Given the timescale of these projects, this factor has to be taken into account as **a huge risk factor**."

A flexible strategy for the future of particle physics at CERN

Key themes from 2026 inputs

- Prioritization of sustainability in design optimization, incl. Life Cyle Assessment (LCA).
- R&D in sustainable accelerator and detector design.
- Sustainable computing infrastructure, from software to hardware.
- Capitalization on technological innovations in energy efficiency and sustainable materials that can contribute to wider development of green economies.
- Attracting, maintaining and growing talent.
- Intertwined issues related to equity, diversity, inclusivity, and accessibility.

Input to European Strategy for Particle Physics: Sustainability

Boisvert et al., https://arxiv.org/abs/2504.03012

Aim: “[Urge] the European Strategy Update in Particle Physics to set a clear and bold mandate for embedding environmental sustainability throughout the future scientific programme, and [advocate] for a series of actions that will enable this.”

These actions can be grouped under:

- **sustainable infrastructure**
- **accountability**
- **knowledge exchange**
- **collateral externalities**

Mitigation versus adaptation

Moral and practical imperatives to act:

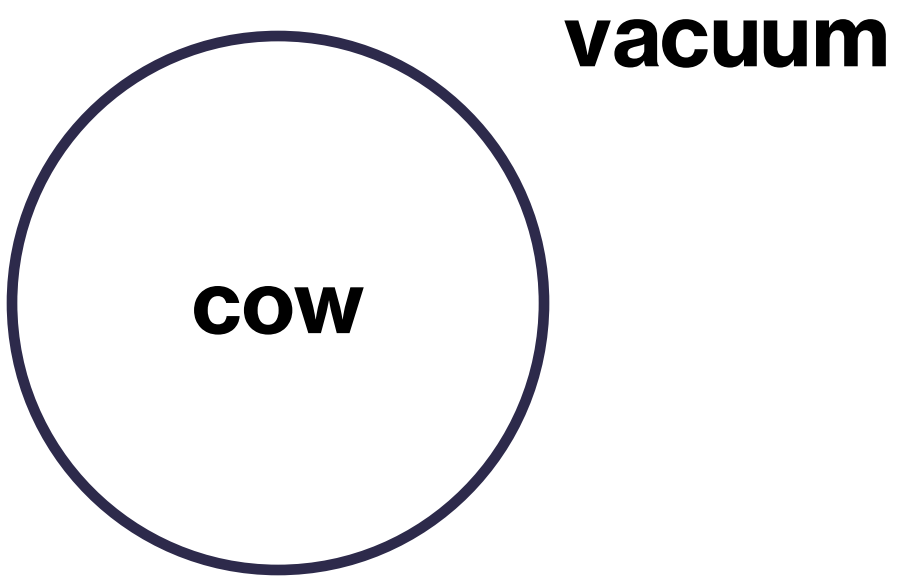
– in **climate mitigation**: reducing energy and material resource consumption, GHG emissions, and other negative environmental impacts.

– in **climate adaptation**: readying our research infrastructure and practices for the manifold challenges posed by climate change. *(Personal opinion: We are behind on this.)*

Some inescapable truths: pressure to justify impacts will increase, and reliance on grid decarbonization will not be enough to guarantee viability of large-scale experiments.

Boisvert et al., https://arxiv.org/abs/2504.03012

There are no proxy problems when it comes to sustainability.



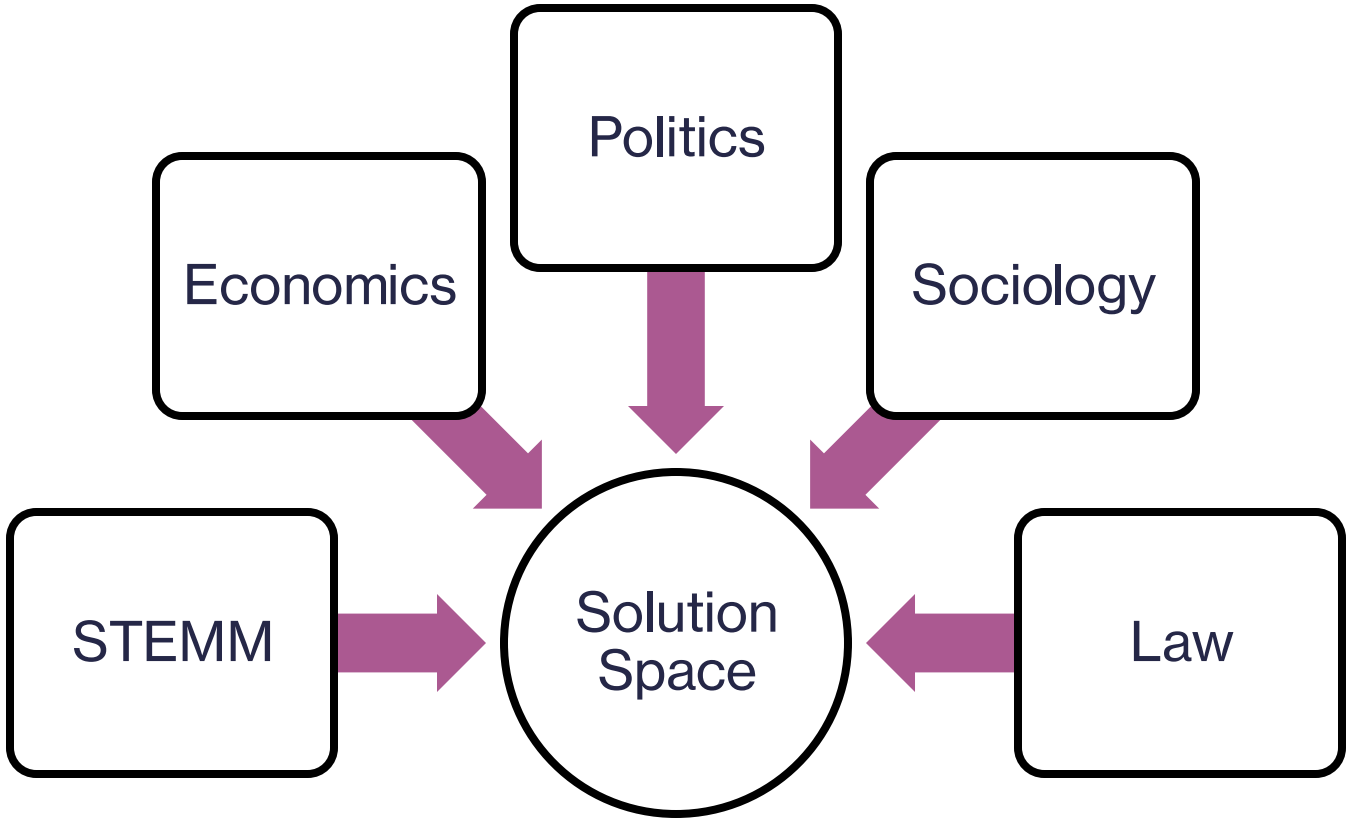
The climate crisis is a wicked problem.

A **wicked problem**:

1. No definitive formulation
2. No stopping rule
3. Not true-or-false, but good-or-bad
4. No solution test
5. No trial and error
6. No enumerable set of solutions
7. Essentially unique
8. A symptom of other problems
9. Numerous representations
10. No right to be wrong

(Rittel and Webber, 1973, https://doi.org/10.1007/BF01405730)

The climate crisis is an interdisciplinary problem.



Challenges

We must acknowledge and **address real and perceived impacts** of change:

– reduced scientific output, and subsequent loss of competitive edge on the level of individuals, collaborations, institutions, nations, and regions;

– less effective dissemination of scientific results;

– decreased international cohesion of scientific effort;

– changes in career and professional development, and the need for upskilling;

– disproportionate impacts on particular groups, e.g., with geographic (or other) isolation, caring responsibilities, health conditions or impairments.

Boisvert et al., https://arxiv.org/abs/2504.03012

Opportunities

A **systems approach** can allow capitalization on co-benefits:

+ for equity, inclusivity, diversity and accessibility

+ for helping to drive the Green industrial revolution

+ for helping to strengthen international relationships

+ for reducing geographic disparities

+ for proactively re-engineering the way that we do our science

+ for collaboration far outside the usual boundaries of our disciplines

Boisvert et al., https://arxiv.org/abs/2504.03012

The bottom line:

"Long-term environmental sustainability must be one of the guiding principles of scientific strategy."

Boisvert et al., https://arxiv.org/abs/2504.03012

RECOMMENDATIONS

We advocate that ...

From Input to European Strategy for Particle Physics: Sustainability
Boisvert et al., https://arxiv.org/abs/2504.03012

Sustainable infrastructure

- Future particle physics projects, including next energy-frontier machines, **be evaluated on** adherence to **principles of environmental sustainability** from design to disposal, based on comprehensive **Life Cycle Assessments (LCAs)**.

- Negative **environmental impacts of** particle physics **computing** be quantified and reduced by **integrating sustainability** into hardware and software practices.

- Existing research **sites be managed and future sites designed** to enhance **habitat diversity**, **halt local biodiversity loss**, **minimize water use**, and **encourage natural water cycles**.

Boisvert et al., https://arxiv.org/abs/2504.03012

Accountability

- All institutions involved in particle physics, including laboratories and universities, publish **environmental reports** at least every two years and use these to define **ambitious emissions targets** that they hold themselves accountable to.

- **CERN**, with its leading role in particle physics, **hold itself to emissions reduction beyond its current targets**, demonstrating the field's commitment to realizing net zero on a timescale compatible with the goals of the Paris Agreement, and **setting the standard for basic scientific research worldwide**.

- Laboratories that host particle physics experiments hold themselves accountable to and **go beyond the environmental pledges of their hosting countries**, including those from which they may be exempt, e.g., the upcoming ban on the emission of fluorinated gases (F-gases).

Boisvert et al., https://arxiv.org/abs/2504.03012

Collateral externalities

- CERN, national laboratories, funding agencies, and institutions develop flexible policies to enable and encourage **environmentally friendly business travel, commuting, and methods of collaboration**.
- CERN, national laboratories, funding agencies, and institutions enable and **encourage practices that minimize food-related GHG emissions** and other **associated negative environmental impacts**.

Boisvert et al., https://arxiv.org/abs/2504.03012

Knowledge exchange

- CERN, national laboratories, funding agencies, and institutions encourage, reward, and **provide opportunities** for their **scientists and engineers to contribute to addressing and communicating the environmental crisis**.

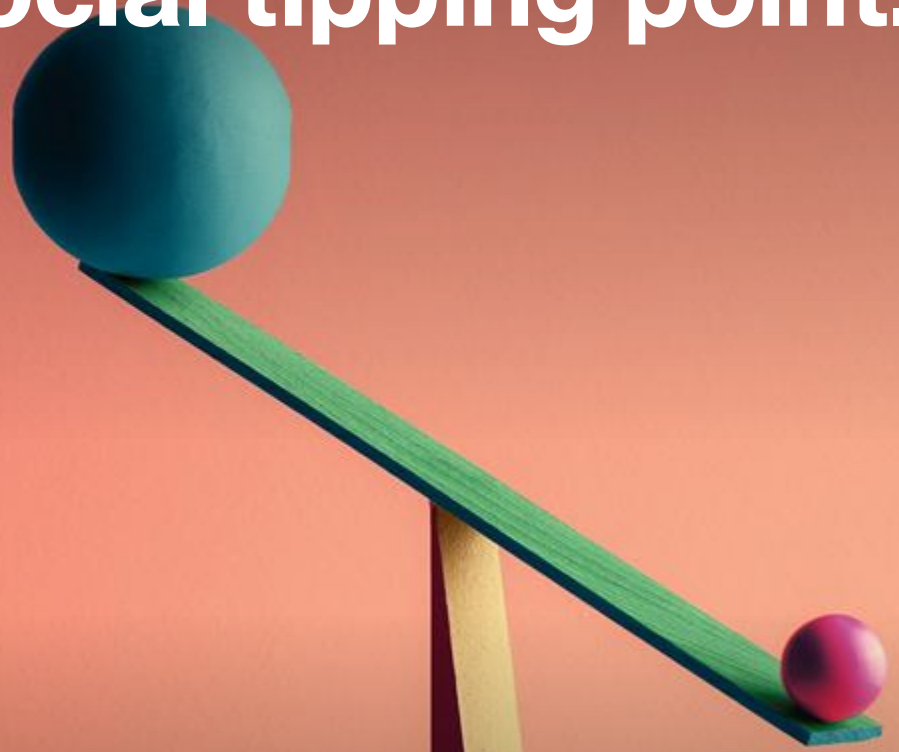
Boisvert et al., https://arxiv.org/abs/2504.03012

Our conclusion

"The climate emergency, biodiversity loss, and chemical pollution of the environment present very real **challenges** and very real **opportunities** for particle physics. To address these challenges and to capitalize on these opportunities requires a large-scale, **systematic and coordinated response** that can be set firmly in motion by **a clear and bold mandate from the European Strategy Update for Particle Physics**. This mandate needs to be far reaching, and it needs to filter through to every aspect of the way that particle physics is done: from the infrastructure that enables it, to the very core of how the international particle physics community operates."

Boisvert et al., https://arxiv.org/abs/2504.03012

ESPP 2026 could help drive our field toward a social tipping point.



A **social tipping point**: small changes trigger a rapid shift in social norms.

There are reasons to be optimistic.

Governance	Strategy	Process	Platform	Research
collaborations	European Strategy Update in PP 2026	ILC and CLIC LCA (Evans 2023)	Dedicated conferences, e.g., Sustainable HEP	labos1point5
institutions	Snowmass 2021 and P5 Report 2023	ESO and GRAND LCAs	Plenary talks and parallel tracks, e.g., ICHEP2024	Innovate for Sustainable Accelerating Systems
funders	ICFA Sustainable Accelerators & Colliders 2024	CERN Environmentally Responsible Procurement Policy		Reduction in F-gases (e.g. LHCb)
				Green computing

See accompanying references for links.

Timeline for the update of the European Strategy for Particle Physics

Source: https://europeanstrategyupdate.web.cern.ch/process-0

There is still time to **strengthen statements** on **sustainability** in **national inputs**.

Timeline for the update of the European Strategy for Particle Physics

Source: https://europeanstrategyupdate.web.cern.ch/process-0

We have an opportunity to shape a truly sustainable, global and equitable cutting-edge science.

Additional references

- labos1point5, https://labos1point5.org/.
- ECFA, “ECFA guidelines for inputs from national HEP communities to the European Strategy for Particle Physics”, CERN, Geneva 2024, https://ecfa.web.cern.ch/ecfa-guidelines-inputs-national-hep-communities-european-strategy-particle-physics-0.
- Butler et al., “Report of the 2021 U.S. Community Study on the Future of Particle Physics (Snowmass 2021) Summary Chapter”, https://arxiv.org/abs/2301.06581.
- Asai et al., “Pathways to Innovation and Discovery in Particle Physics. Report of the 2023 Particle Physics Project Prioritization Panel”, 2023, https://www.usparticlephysics.org/2023-p5-report/investing-in-the-future-of-science-and-technology.html#69sustainability-and-the-environment.
- S. Evans and B. Castle, “Life Cycle Assessment. Comparative environmental footprint for future linear colliders CLIC and ILC. Final Report. July 2023,” Geneva, 2023. https://edms.cern.ch/ui/#!master/navigator/document?D:101320218:101320218:subDocs
- ESO, “Environmental sustainability at ESO, “https://www.eso.org/public/germany/about-eso/green/”.
- C. Aujoux et al., “Estimating the carbon footprint of the GRAND project, a multi-decade astrophysics experiment,” Astroparticle Physics, vol. 131, p. 102587, 2021. https://doi.org/10.1016/j.astropartphys.2021.102587
- IPT Department, CERN, “Mitigating the environmental impact of CERN procurement”, CERN, 2024, https://home.cern/news/news/cern/mitigating-environmental-impact-cern-procurement.
- ICFA Panel on Sustainable Accelerators and Colliders, https://icfa.hep.net/icfa-panel-on-sustainable-accelerators-and-colliders/.
- J. D'Hondt, “Innovate for Sustainable Accelerating Systems (iSAS)”, 2023, https://indico.cern.ch/event/1242680/attachments/2583397/4456219/Sustainability-HorizonEurope-JDH-v3-Jan2023.pdf.
- LHCb Collaboration, “Framework TDR for the LHCb Upgrade II – Opportunities in flavour physics, and beyond, in the HL-LHC era,” https://cds.cern.ch/record/2776420, CERN, Geneva, Tech. Rep., 2021.
- L. Lannelongue, J. Grealey and M. Inouye, “The Green Algorithms project”, 2022, https://www.lannelongue.eu/research/green-algorithms/.